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54 **A lipolytic enzyme derived from a aspergillus microorganism having an accelerating effect on cheese flavor development.**

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- 56 References cited:
CA-A- 1 091 978
US-A- 3 975 544

ARCH. BIOCHEM., vol. 30, 1951, pages 165-179; W.F. SHIPE Jr.: "A study of the relative specificity of lipases produced by Penicillium roqueforti and Aspergillus niger"

73 Proprietor: **GENENCOR, INC.**
180 Kimball Way
South San Francisco California 94080(US)

72 Inventor: **Arbige, Michael Vincent**
363 Thunder Circle
Bensalem Pennsylvania 19020(US)
Inventor: **Neubeck, Clifford E.**
45 Horsham Road
Hatboro Pennsylvania 19040(US)

74 Representative: **Smith, Sydney et al**
Elkington and Fife Prospect House 8 Pembroke Road
Sevenoaks, Kent TN13 1XR(GB)

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DescriptionTechnical Field

5 The present invention relates to a novel Aspergillus microorganism and to a novel lipolytic enzyme derived therefrom. Cheese aged in the presence of a low concentration of this lipolytic enzyme ripens faster than with conventional lipolytic enzymes and without any lipolytic enzyme-associated rancidity.

Background Art

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Accelerating of cheese aging to improve cost efficiency through a reduction of storage space is becoming more important to the cheese industry. Currently, lipases from two different sources, animal pregastric glands, and animal pancreases, are being added to cheese curd as accelerators. A third source, microbial lipases, has been used for production of strongly flavored cheeses, but not mild cheeses.

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Lipases derived from the pregastric gland of kid, calf and lamb are currently being added to accelerate ripening in cheese of Italian type (Provolone, Romano, Parmesan) where the characteristic rancid flavor of low molecular weight free fatty acids (e.g. butyric acid) is desirable. However, when these pregastric lipases are used to accelerate mild flavored cheese, e.g. Cheddar, too much of the low molecular weight fatty acids are produced and a rancid flavor develops. When the animal pancreas lipases are used in a high concentration, excessive amounts of lauric acid is produced in the cheese, making a soapy taste. Moreover, unless highly purified, these lipases can contain an abundance of protease which although in small amounts aids cheese softening, in larger amounts it produces bitter off-flavors.

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In the search for lipases showing desirable ripening characteristics, numerous organisms such as Pseudomonas fragii, P. fluorescens, Staphylococcus aureus, Clostridium lipolytica, Geotrichium candidum, Penicillium roqueforti, Aspergillus niger, A. flavus, A. oryzae, Candida cylindracea and Rhizopus oligosporus, have been used in laboratory studies. Many of these microbial lipases are not yet available commercially. In a study of various lipases for cheese ripening, Harper, W.J., [J. Dairy Science 40 556 (1957)], the following data has been developed with respect to selective liberation of free fatty acids from 20% butterfat cream.

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Table 135 **Release of Free Fatty Acid from 20% Butterfat Cream**

<u>Lipase Source</u>	<u>Mol. % Butyric</u>	<u>% Produced in 3 hrs. Caproic</u>	<u>Caprylic</u>	<u>@ 35 C Capric</u>	<u>Lauric</u>
40 Imported kid rennet (paste)	32.8	11.3	7.1	11.8	33.6
Pregastric esterases					
45 kid	44.4	15.2	7.6	12.3	21.5
lamb	48.1	8.6	14.2	9.3	19.3
calf	36.7	8.9	14.8	10.7	39.0
Domestic calf rennet	10.7	3.1	trace	trace	86.5
Milk lipase	13.5	8.2	10.2	8.7	60.0
50 Pancreatic lipase	8.4	2.1	trace	trace	89.1
<u>A. niger</u> lipase	43.1	18.9	20.2	17.5	trace

55 Little information is available on the relationship between specific free fatty acids and flavor intensity in cheese although the presence of butyric acid usually is associated with strong rancidity development in strong cheese and the presence of large amounts of lauric may lead to a soapy flavor. Longer chain fatty acids have been linked to fruity flavors. It is generally noted that all of the even numbered free fatty acids are present but the concentration of the specific fatty acids varies in different types of cheese.

Disclosure of the Invention

The present invention relates to isolated cultures of a selected mutant strain of Aspergillus fungus. When cultured in a suitable nutrient medium, under proper aeration and agitation, it produces a novel lipolytic enzyme. For the purposes of this disclosure, this type of enzyme shall be referred to as a lipase although esterases are included in this term.

The novel strain of fungus according to the invention has been identified as a novel strain of Aspergillus. This has been deposited in the America Type Culture Collection 12301, Parklawn Drive, Rockville, Maryland 20852, United States of America under No. 20719.

According to one aspect of the invention, therefore, there is provided a biologically pure culture of a strain of Aspergillus having the deposition number ATCC 20719.

The Aspergillus organism according to the invention makes a novel and especially useful lipase when cultured in an oil-based medium in the same manner as known Aspergillus organisms. However, the lipase from the novel Aspergillus hydrolyzes longer chain C_6 and C_8 triglycerides such as tricaproin and tricapyrin more efficiently than short chain C_4 triglycerides such as tributyrin.

Lipase having this characteristic appears to be useful as a ripening accelerator in mild flavored cheese production, such as Cheddar cheeses. The less efficient hydrolysis of the shorter C_4 triglycerides suppresses the development of rancid flavors which are unwanted in mild cheeses.

When isolated from the present Aspergillus organism under proper dilution, agitation, pH, and salt concentration conditions, the present lipase is associated with low levels of protease which soften the cheese without producing bitter flavors.

Brief Description of the Drawings

FIGURE 1 is a graph showing the effect of mycelium concentration on lipase release.

FIGURE 2 is a graph showing the effect of temperature on lipase activity at pH 6.2.

FIGURE 3 is a graph showing the effect of pH on lipase activity at 33° C.

FIGURE 4 is a graph showing the effect of temperature on lipase activity at various pHs.

FIGURE 5a-f are graphs showing the effect of time on lipase activity at various temperatures and pHs.

FIGURE 6 is a graph showing the effect of time on tricapyrin hydrolysis by the present lipase at 40° C.

FIGURE 7 is a graph showing the effect of time on tricapyrin hydrolysis by the present lipase at 50° C.

FIGURE 8 is a graph showing the percent hydrolysis of a specific free fatty acid to total free fatty acid in enzyme-added cheeses.

FIGURE 9 is a graph showing the percent hydrolysis of a specific free fatty acid to total free fatty acid in enzyme-added cheeses.

Modes for Carrying Out the InventionCulturing the Organism

The Aspergillus organism is stored on sterile soil under refrigeration. Portions of the soil stock are transferred to potato dextrose agar (PDA) and grown 4-5 days at 20-35° C, 30° C preferably, to use as primary inoculum for shake flask and fermenter growth.

Lipase can be made in a shaker flask by inoculating directly from the PDA slant into 100 ml. of sterile medium at pH 5.1 (5.0-5.2) containing 6% soy bean meal, 5% monobasic ammonium phosphate, 0.5% Magnesium sulfate (crystal), 2% soy oil, 1L Erlenmeyer flasks. After 3-5 days at 30° C and an agitation of 265 RPM, the culture is filtered. Preferred ranges for culture ingredients are: 1-10% oil; >.1-1% sulfate; 1-5% phosphate; and 3-8% soybean meal. The concentrations of $MgSO_4$, $(NH_4)_2H_2PO_4$ and oil is important to optimum production of lipase activity. The initial pH must not be below 5.0.

Production in a fermenter requires some modifications. The medium components are as described for shake flasks, but it is necessary to use an intermediate step of inoculum to reduce the growing time to the interval of 3-5 days. The inoculum volume used is 5% (1 to 10) of a nutrient containing 4% whole wheat flour and 8% corn steep water at pH 5.5. The sterile inoculum nutrient is inoculated with the PDA slant and grown 30-50 hrs. at 30° C and then transferred to the growing medium. Here, the oil may be corn or soy oil and the concentration may be from 1-6%. All of the oil can be present initially or added in increments after growth has started.

Preparing the Lipase

Filtering the fungal mycelium effectively isolates the lipase. The lipase activity of the crude culture when harvested (pH 4.5-5.0) is bound to the mycelium. The mycelium-free culture filtrate contains essentially no lipase activity (<5%), and all soluble extracellular components which may have a negative effect on cheese flavor.

5 Release of lipase activity from the mycelium into a second extraction filtrate depends on the concentration of the mycelium, the pH, the buffer salt concentration of the extraction filtrate (0.5-3.0% PO₄ at optimum pH), the concentration of surfactant (preferably <1%), and the treatment time.

10 Fig. 1 illustrates how the amount of lipase released to extraction filtrate using Ethofot 242/25 surfactants varies according to the concentration of mycelium. All of this data was obtained at pH 6.2. Optimal recovery of lipase from mycelium is achieved normally at pH 6.2 because the lipase (free from mycelium) shows excellent stability for long periods. As the pH increases the lipase is less stable, and it is actively destroyed above pH 7.5. For example, after 42 hours at 4-5° C filtrate showed 94%, 87% and 74% activity retention respectively at pH 6.3, 6.8 and 7.4. After treatment under optimal conditions, about 80-90% of the lipase activity can be recovered from the mycelium filtrate.

15 The lipase in the extraction filtrate can be used directly for cheese flavor modification or alternatively concentrated in vacuo or by ultrafiltration before cheese addition. The filtrate or concentrate can be dried in vacuum at 0-35°C or spray dried to produce a dry concentrate which can be blended with other components, e.g. sodium chloride, phosphates, etc., used routinely in cheese manufacture. The methods of concentration and drying are conventional techniques known to those of ordinary skill in the art.

20 Assaying Lipase Activity

Two different assays have been used for lipase activity. In the first, potentiometric titration is performed so as to determine lipase forestomach units (LFUs). One LFU equals the activity that releases 1.5 μ mol of butyric acid per minutes, Food Chemical Codex 3rd Ed., National Academic Press, 1981.

The titration substrate is prepared by dispersing an amount of sodium caseinate equivalent to 600 mg of casein, in 95 ml of water contained in a one-half pint freezer jar that fits the head of a suitable high-speed blender. This is mixed with 0.5 gm of hydroxylated lecithin. Finally 5.0 ml of Tri-n-butyryn is added and mixed for 60 sec. at low speed. This substrate must be held to 33° C and used within 4 hours.

30 The sample is prepared by suspending or dissolving an accurately weighed amount of enzyme in water.

To measure, the titrator is filled with 0.05 N sodium hydroxide, and the instrument is calibrated following the manufacturer's instructions. The substrate is mixed for about 15 sec with a magnetic stirrer, then 20.0 ml is pipetted into the reaction vessel of the titrator. One ml of the sample is added and equilibrated for 15 min. The rate, in ml per min., at which the titrant was delivered during the titration, is determined and recorded as R. The activity of the enzyme is calculated by the formula:

$$\text{LFU/g} = R \times 0.025 \times 10^3 / (W \times 1.25),$$

40 in which W is the weight, in g, of the enzyme preparation contained in the 1.0 ml of Sample taken for analysis.

It should be noted that the enzyme's ability to hydrolyze tricaproin (C6), tricapyrylin (C8), tricaprln (C10), can be measured simply by replacing tri-n-butyryn with the desired substrate.

45 A second assay is the cream-acid titration method. An aliquot (20.0 ml) of 10.5% butterfat Half and Half is placed into 2 oz. glass jars and brought to 33° C in thermostated water bath. After temperature equilibrium has been established (about 10 minutes), 1.0 ml of enzyme solution is added and incubated for 2 hours. Then 10 ml of ethanol (denatured formula 2A is suitable) is added to stop the reaction before titrating with 0.05N NaOH to pH 9.5. The titration should be carried out with a glass electrode and the incubation mixture plus alcohol should be stirred with a magnetic bar.

50 A substrate control (20 ml half & half plus 10 ml water) is run to correct for the amount of alkali required to neutralize the salts present in the cream.

An enzyme control is also run to correct for the amount of alkali required to neutralize the salts present in the enzyme.

55 The increase in acidity corresponding to a 1% hydrolysis of the butterfat is equivalent to a titration difference of 1.65 ml 0.05N NaOH. Activity is calculated from the following relationship:

$$\text{CLU} = \frac{0.05\text{N NaOH produced in 20 ml Substrate}}{\text{g Enzyme used}}$$

5

Effect of pH, Temperature and Time on Lipase Activity

10 The effects of temperature and pH on tributyrin hydrolysis by the present lipase is noted in Figs. 2-4. As seen in Figure 2, the optimum temperature for enzyme activity is approximately 42.5 °C, while Figure 3 shows that the optimum pH is close to 7.0. A sharp decrease in activity as the temperature is raised can be seen in Figure 4, the effect being more dramatic with an increase in pH. The plots given in Fig. 5a-f also indicate that an increase in time accentuates the adverse effect of pH values above 6.2, although pH 7.0 is clearly optimal at temperatures below 60 °C.

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Triglyceride Hydrolysis

20 The present lipase has been used to hydrolyze specific triglycerides (tricaprylin, tricaproin, and tributyrin) into their respective free fatty acids (FFAs) (caprylic, caproic, and butyric acids. Conventional gas chromatography techniques can be used to measure these FFAs.

Hydrolysis has been measured in the following manner. Five gm of triglyceride is blended with 100 ml phosphate buffer (pH 6.5, 0.05 m) containing 1% gum arabic to form an emulsion, which is shaken with 2.0 ml of fungal lipase (100 mg) for 4 hours at 33 °C. To stop the reactions, 10 ml of ethanol is added, and the resulting free fatty acids are measured by gas chromatography.

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The free triglyceride hydrolysis results are as follows:

Table 2

Enzyme Treated Substrate	% Free Fatty Acid	Ratio (C ₈)/C ₄
Tributylin (C4)	3.39	1.00
Tricaproin (C6)	3.76	1.11
Tricaprylin (C8)	5.26	1.55

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The present lipase hydrolyzes both tricaproin and tricaprylin more efficiently than it hydrolyses tributyrin. This type of hydrolysis can be demonstrated by taking a ratio of the two numbers (C₈/C₄). Increased rate of hydrolysis can be shown by the ratio TC/TB. Typically, the increased rate of activity results in equivalent C₈/C₄ production. This specificity is unique for the present lipase.

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The following table shows the tricaprylin (TC) to tributyrin (TB) hydrolysis ratio (TC/TB) for known lipases, as cited by known authors:

TABLE 3

45

RELATIVE ACTIVITY OF LIPASE PREPARATIONS AS CITED IN LITERATURE

50

<u>Preparation</u>	<u>Activity vs. Tributyrin</u>	<u>Activity vs. Tricaprylin</u>	<u>TC/TB</u>	<u>Cite</u>
Hog pancreas	100	37	0.37	Enzymologia
Human milk	100	59	0.57	<u>11</u> 178 (1944)
Bovine pancreas	100	41	0.41	

55

Release of FFA from Milk Fat

	mol % <u>C₄</u>	mol % <u>C₈</u>		
5 Milk Lipase	13.9	1.8	0.13	Nelson J.H.
Steapsin	10.7	1.5	0.14	J. Amer Oil
Pancreatic Lipase	14.4	1.4	0.09	Chem Soc
10 Calf Esterase	35.0	1.3	0.04	49 559
Esterase pancreatin	15.83	3.0	0.19	1972
Calf pregastric esterase	40.8	8.6	0.21	Farnham
Kid pregastric esterase	50.0	8.4	0.17	et al
15 Lamb pregastric esterase	44.8	8.3	0.19	1956

% of Total Free Fatty Acids (microequivalent basis)
after 3 hrs. at 35°C on milk fat

20 Imported crude kid	32.8	7.1	0.22	Harper W.J.
rennet paste				
Domestic purified calf	10.7	trace	.00	J. Dairy Sci
rennet paste				
Calf oral lipase	36.7	4.8	0.13	40 556 (1957)
25 Kid oral lipase	44.4	7.6	0.17	
Lamb oral lipase	48.1	14.2	0.30	
Aspergillus lipase	43.1	20.2	0.47	
Milk lipase	13.5	10.2	0.76	
Pancreatic lipase	8.4	trace	.00	

u moles FFA liberated/ml enzyme

35 <u>Syncephalastrum</u>	11.2	7.6	0.68	Chopra et al
<u>racemosum</u>				J. Dairy SC 65
				1890 (1982)

ml 0.1N Acid Produced in 2 hrs. 30°C

40 <u>Penicillum roqueforti</u>	1.45	0.56	0.39	
<u>Aspergillus niger</u>	1.20	2.18	1.82	Shipe, W.F.
				Arch. Bioch. 30
				165 (1951)

45 Figures 6 and 7 illustrate the significantly better TC hydrolysis versus TB hydrolysis of the present lipase and how it can be increased with temperature. At 40°C and pH 7.0 the TC/TB ratio is 1.73, while at 50°C and pH 7.0 it is an even greater 2.49.

Milk Triglyceride Hydrolysis

50 The present lipase has been tested for hydrolysis of those triglycerides present naturally in milk. To test for hydrolysis, 180 ml of 10.5% butter fat cream is treated with 0.36 g (0.2%) and 0.90 g (0.5%) of either the present lipase or calf lipase. Samples are held for 15 days at 0-3°C before free fatty acid (C4 to C12) is determined by gas chromatography. A control cream sample without enzyme is carried also through the

55 experiment.

The results of the milk test are as follows.

TABLE 4

Mg FFA/ml cream					
Specific FFA	Control	0.2% Present Lipase	0.5% Present Lipase	0.2% Calf Lipase	0.5% Calf Lipase
C4	0.18	0.37	0.52	0.38	0.53
C6	0.09	0.32	0.43	0.13	0.20
C8	0.10	0.20	0.27	0.12	0.15
C10	0.14	0.30	0.41	0.20	0.16
C12	<0.05	<0.05	0.09	0.05	0.05

TABLE 5

% Hydrolysis of Specific Glyceride					
Specific FFA	Control	0.2% Present Lipase	0.5% Present Lipase	0.2% Calf Lipase	0.5% Calf Lipase
C4	6.0	12.3	17.3	12.7	17.7
C6	4.5	16.0	21.5	6.5	10.0
C8	11.9	23.8	32.1	14.5	17.8
C10	8.3	17.9	24.4	11.9	9.5
C12	<0.8	<0.8	1.5	0.8	0.8

TABLE 6

% Hydrolysis of Specific Glyceride (Corrected for FFA present in Control)				
Specific FFA	0.2% Present Lipase	0.5% Present Lipase	0.2% Calf Lipase	0.5% Calf Lipase
C4	6.3	11.3	6.7	11.7
C6	11.5	17.0	2.0	6.0
C8	11.9	20.2	2.6	5.9
C10	9.6	16.1	3.6	1.2
C12	0	(0.7)	0	0

Although FFA production of the present lipase is nearly identical to that of calf lipase for C4 production, all of the other FFA data show that the present lipase hydrolyzes the glycerides of C6, and C8, and C10 to a much greater extent. For example the present lipase shows, respectively, 5.8x, 4.6x, 2.7x more C6, C8, C10 than the calf lipase at 0.20% concentration, and 2.8x, 3.4x and 13.4x at 0.50% concentration.

Triglyceride Hydrolysis in Oils

The present lipase has been tested also for production of 5% emulsions of soy, butter, and coconut oils. Chromatography of the treated emulsions (4 hours at 33° C) reveals the ability of this lipase to hydrolyze a whole range of triglycerides. The level of certain triglycerides in the mixtures and the ability to fully emulsify the substrates can alter the rate of specific free fatty acid released as illustrated in Table 7.

Fatty Acid Determined	Soy Oil % FFA	Butter Oil % FFA	Coconut Oil % FFA
C2	**ND	ND	ND
C4	ND	0.16	ND
C6	ND	0.066	0.029
C8	ND	0.014	0.19
C10	ND	0.062	0.042
C12	ND	0.19	0.22
C14	ND	0.062	0.047
C16			
C18	0.13	0.57	0.57
C18-1	0.97	0.072	0.072
C18-2	3.25	0.24	1.61

**ND = none detected

Cheese Preparation

Cheese has been made with the present lipase in the following manner. Milk is obtained from a dairy farm, batch pasteurized at 62.5° C (145° F) for 30 minutes, and then held at 2.5° C (36° F) until the following day. (Colby cheese is made using Hansen CH 60Y™ as a starter). Equivalent activity amounts of the present lipase and Miles 600 calf lipase (by cream assay) are preweighed and mixed with salt to give 2% salt by weight. Eight treatments of the cheese are made using 20 pound blocks. Control blocks with salt but without enzyme are made as well.

The resulting cheeses are sampled at 1, 28, 72, 102, and 198 days. They are evaluated organoleptically and analyzed for free fatty acids by gas chromatography, known acid degree value (ADV) tests, and also by 12 % TCA soluble nitrogen tests.

After 72 hours, the cheeses having 0.048% present lipase and 0.128 calf lipase have about the same ADV and total FFA, which is 50-70% greater than that of the control. However, at 102 and 198 days, the concentrations of enzyme used (and for which data has been tabulated) are too high for good flavor in that too much free fatty acid has developed. The calf lipase produces too much butyric acid, and the present lipase, too much total free fatty acid C14-C18.

At lower concentrations (0.012 and 0.024%) the present lipase gives good aged flavor without rancidity associated with butyric acid at 102 days. The control has weak flavor at this point, while the calf lipase showed the typical rancidity associated with butyric acid at days, even with low levels of the enzyme preparation (0.064 and 0.032%).

Figs. 8 and 9 illustrates the triglyceride hydrolysis data for the control cheese and cheeses prepared with 0.048% NM 313 lipase and 0.128% calf lipase. It is readily apparent that at 72 days and 102 days, the butyric acid content in cheese made from the calf lipase is very elevated over that of the control. On the other hand, cheese made with the present lipase is more like the control cheese as far as butyric acid levels.

The present lipase reduces the mild cheese aging process by 2-5 times. At 102 days the present lipase-added cheese shows greater C16, C18, C18-1 and C18-2 content than the control cheese, indicating an acceleration (i.e. more rapid flavour development) of the usual ripening process. Thus, cheeses manufactured with the present lipase develop a Cheddar like flavor while those of the calf lipase produces an Italian type flavor. It is apparent that the lipase derived from the present *Aspergillus* organism is unique in shortening the storage time needed for Cheddar and other mild flavored cheeses.

50 Claims

1. A biologically pure culture of a strain of *Aspergillus* having the deposition number ATCC 20719.
2. A lipolytic enzyme obtainable from the culture claimed in claim 1 characterised in that it is capable of increasing the speed of maturation of cheese without increasing rancidity and bitterness thereof.
3. A method of producing a mild cheese characterised in that it includes the step of adding to cheese curd or milk a lipolytic enzyme as claimed in claim 2.

4. A method as claimed in claim 3 characterised in that the mild cheese is Cheddar Cheese.

Patentansprüche

- 5 1. Biologisch reine Kultur eines Stamms von *Aspergillus* mit der Hinterlegungsnummer ATCC 20719.
2. Lipolytisches Enzym erhältlich aus der Kultur nach Anspruch 1, dadurch **gekennzeichnet**, daß es dazu imstande ist, die Reifungsgeschwindigkeit von Käse ohne Erhöhung seiner Ranzigkeit und Bitterkeit zu steigern.
- 10 3. Verfahren zur Herstellung eines milden Käses, dadurch **gekennzeichnet**, daß es die Stufe der Zugabe eines lipolytischen Enzyms nach Anspruch 2 zu Käsequark oder zu Milch einschließt.
4. Verfahren nach Anspruch 3, dadurch **gekennzeichnet**, daß der milde Käse Cheddar-Käse ist.

15

Revendications

1. Une culture biologiquement pure d'une souche d'Aspergillus ayant le numéro de dépôt ATCC 20719.
- 20 2. Une enzyme lipolytique pouvant être obtenue à partir de la culture de la revendication 1, caractérisée en ce qu'elle est capable d'accélérer l'affinage d'un fromage, sans en accroître la rancidité ni l'amertume.
3. Un procédé de production d'un fromage doux, caractérisé en ce qu'il comprend l'étape d'addition, au
- 25 caillé de fromage ou au lait, d'une enzyme lipolytique selon la revendication 2.
4. Un procédé selon la revendication 3, caractérisé en ce que le fromage doux est un fromage cheddar.

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EFFECT OF MYCELIUM CONCENTRATION
ON RELEASE OF LIPASE FROM MYCELIUM

Fig. 1

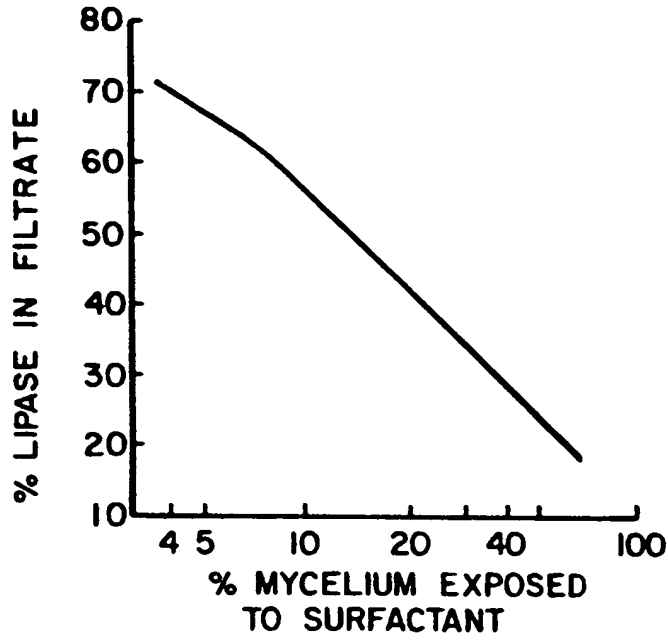
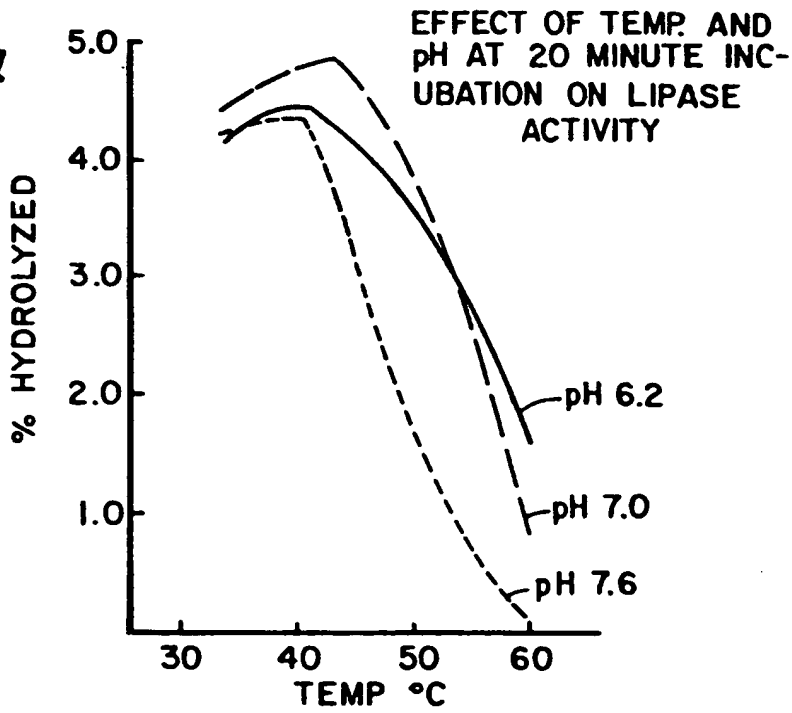


Fig. 4



EFFECT OF TEMP. ON LIPASE ACTIVITY
(pH 6.2)

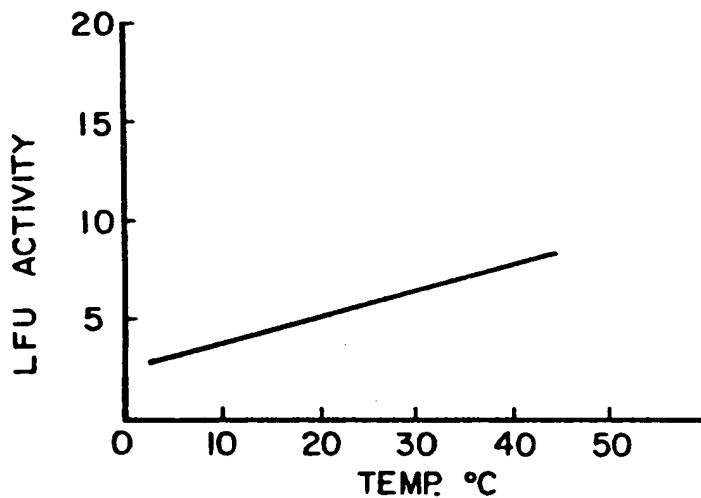


Fig. 2

EFFECT OF pH ON LIPASE ACTIVITY
T = 33°C

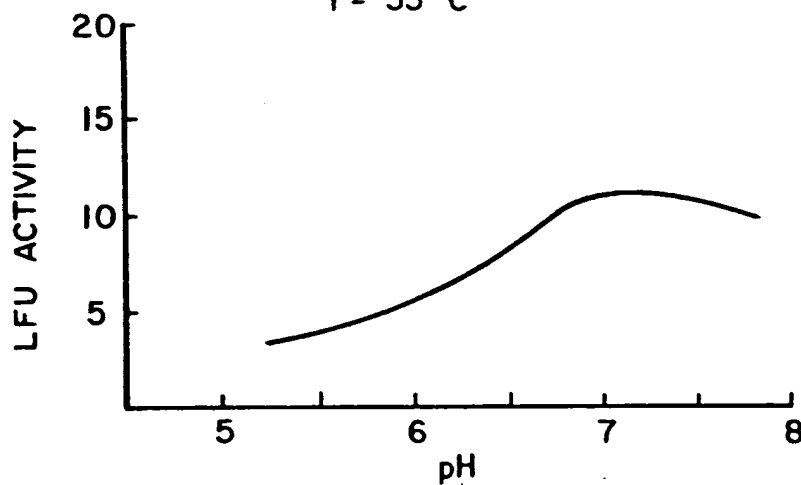


Fig. 3

EFFECT OF TIME ON LIPASE ACTIVITY
AT 33° C - 40° C - 42.5° C

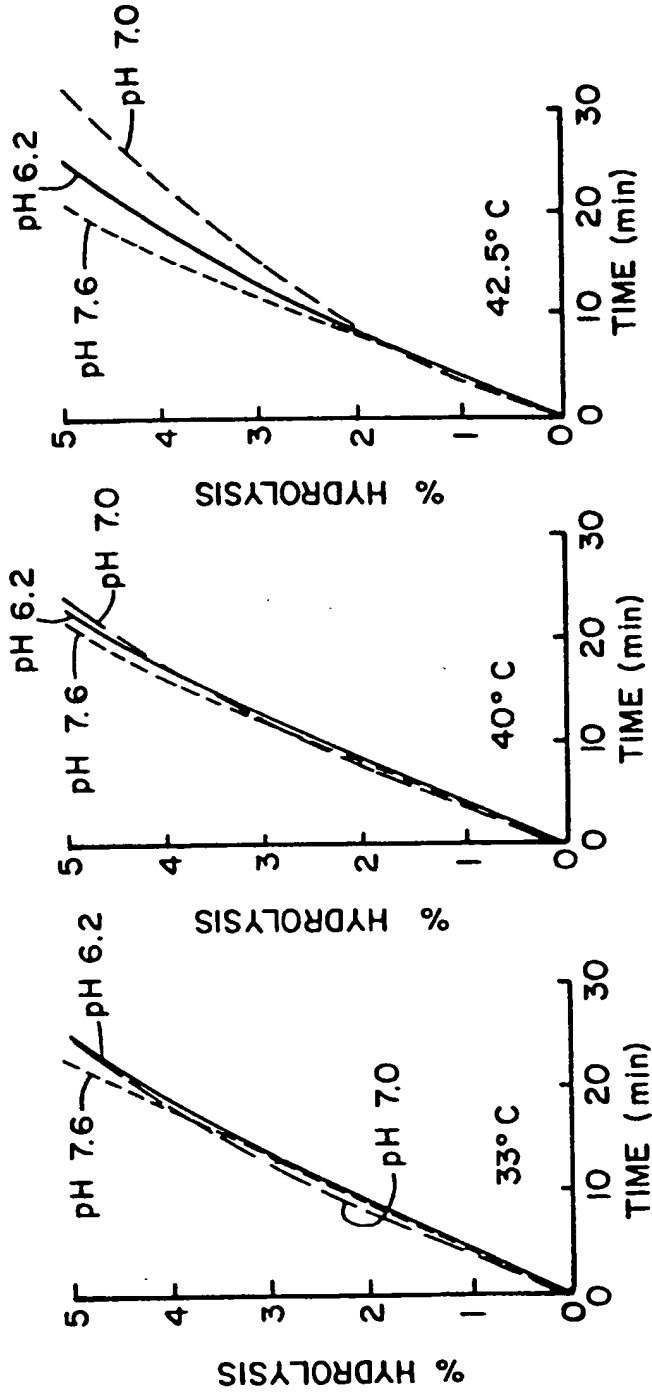


Fig. 5a

Fig. 5b

Fig. 5c

EFFECT OF TIME ON LIPASE ACTIVITY
AT 45°C — 50°C — 60°C

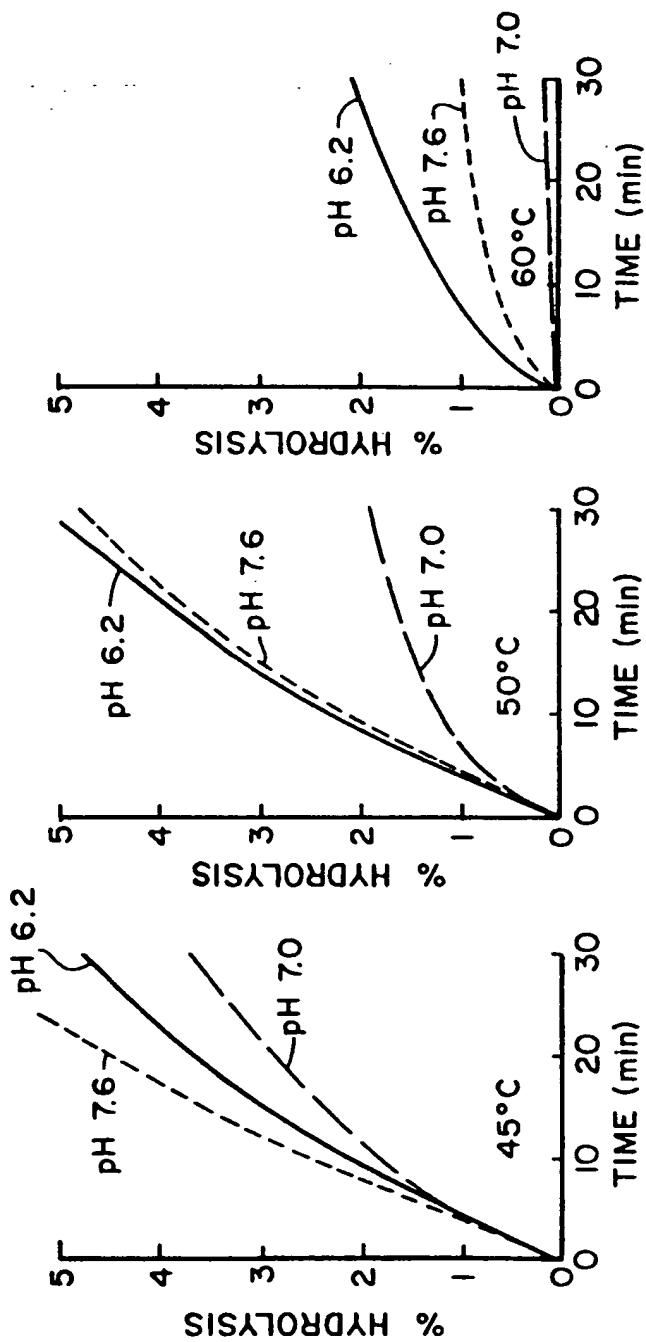


Fig. 5f

Fig. 5e

Fig. 5d

EFFECT OF TIME ON TRICAPRYLIN HYDROLYSIS

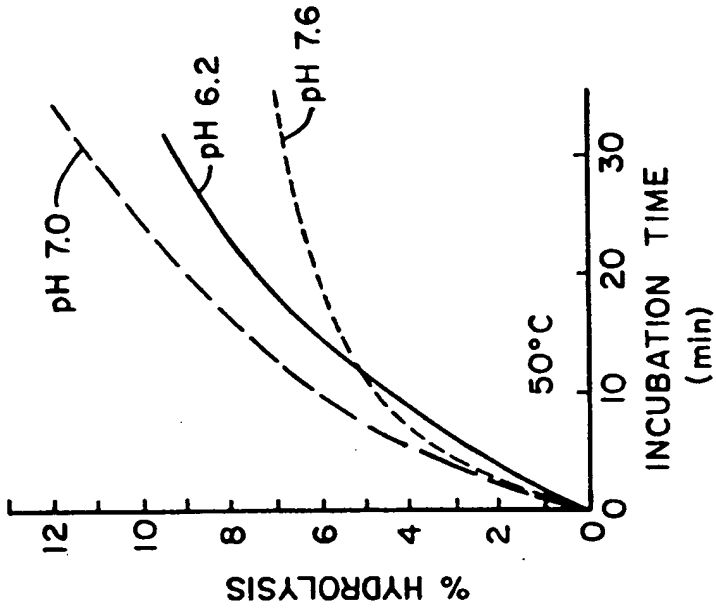


Fig. 7

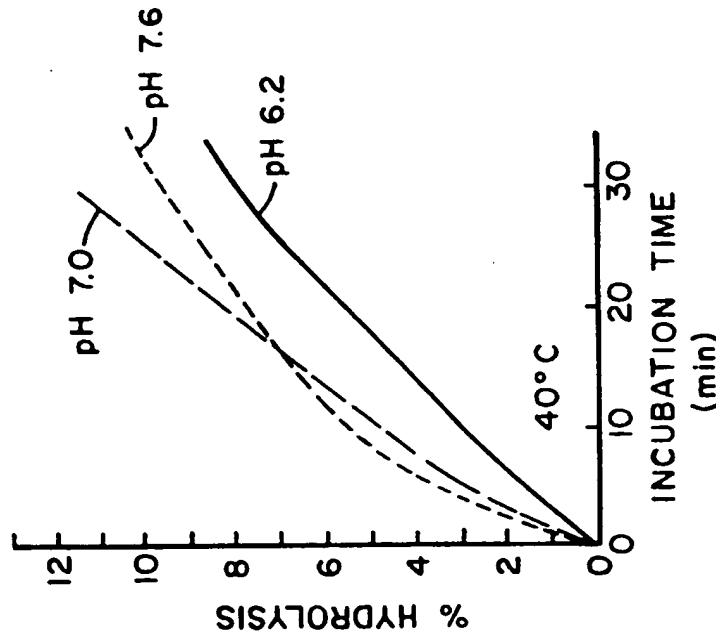


Fig. 6

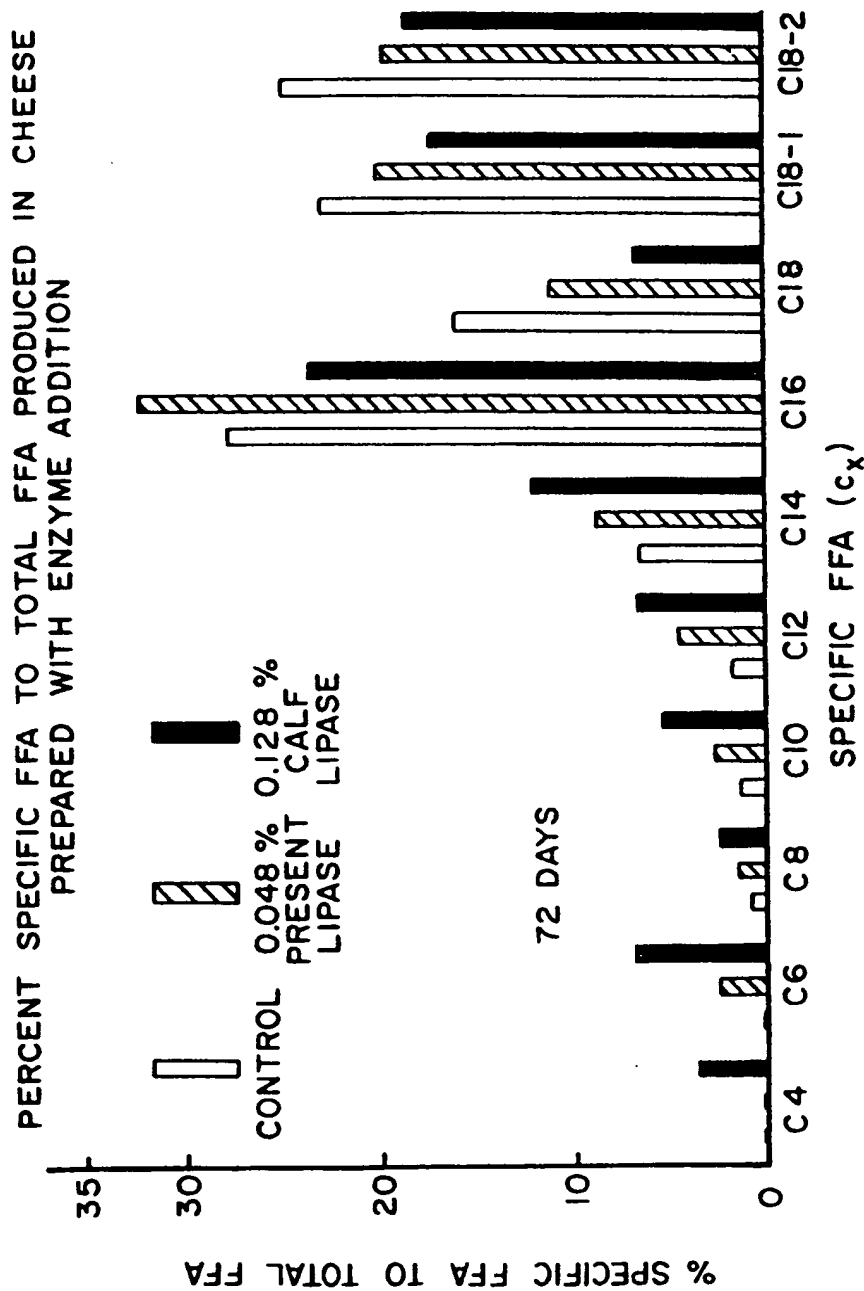


Fig. 8

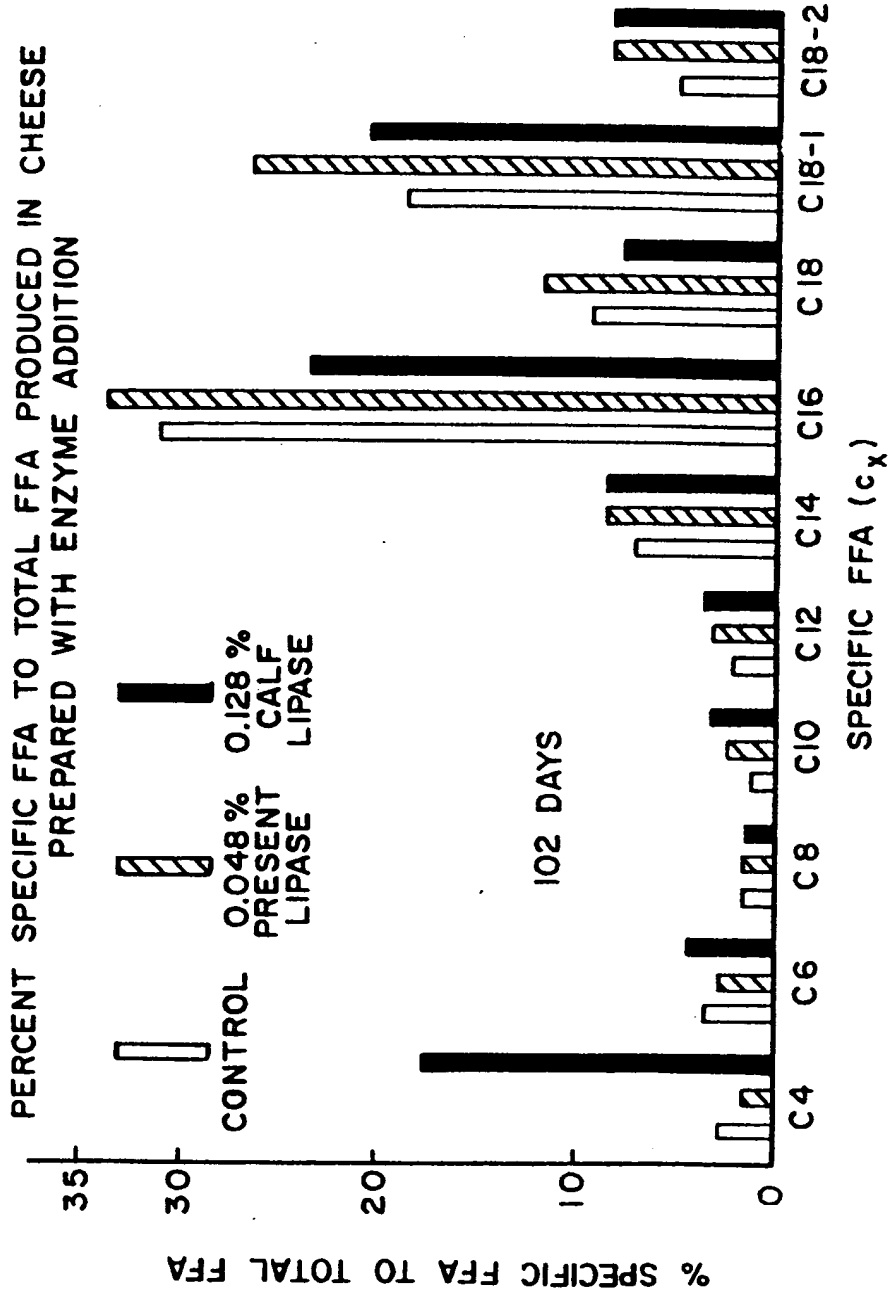


Fig. 9